ANALYSIS OF DIAGNOSTIC SUSCEPTABILITY OF A HEAVY FUEL OIL PURIFICATION SYSTEM

ANALIZA PODATNOŚCI DIAGNOSTYCZNEJ WIRÓWKI PALIWA LEKKIEGO

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Anotace:

Na przykładzie wirówki wchodzacej w skład sytemu przygotowania paliwa lekkiego siłowni okrętowej dokonano opisu możliwości pomiaru parametrów pracy wirówki pod kątem diagnozowania jej pracy. Intensywność uszkodzeń poszczególnych podzespołów wirówki przyjęto na podstawie danych literaturowych i własnych obserwacji obiektów rzeczywistych. Dokonano analizy występujących i możliwych do wystąpienia uszkodzeń poszczególnych podzespołów wirówki. Korzystając z metody tabelarycznej rejestracji parametrów wejściowych i wyjściowych, dokonano analizy ilości i jakości rejestrowanych parametrów pad kątem wykorzystania ich do diagnostyki i oceny stanu zdatności opisywanego urządzenia.

Summary:

A system of heavy fuel oil purification has been analyzed in terms of quality and quantity of measurement points and possibilities of practical use of selected diagnostic tests. The Boolean matrix method as well as the one-by-one testing method have been used. Presented is an analysis of a matrix of energetic fluids flow in a system of heavy fuel purification. After the analysis flow matrix and summing up the control points for individual devices, an examination was carried out to find if all the branches of the system are permanently monitored as it is known that a system without points from which the operator can obtain information on the system state is subject to more frequent failures.

1. Introduction

A marine power plant is a complex technical system whose main goal is to fulfill the pre-set functions. The construction of such complex and capital-consuming technical item is preceded by the phases of technical and economic analyses, guidelines preparation, preliminary and construction designing. Permanently growing requirements as regards smooth, failure-free operation of marine power plants, reduction of economic costs, enhancing the safety of operators have been a major motivation for the development of diagnostic systems.

The capability of determining the up state of a system or device by diagnostic tests can be called diagnostic susceptibility.

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Effective minimization of the threats to the system, determining an increase in safety, quality and effectiveness of systems, is possible if we consider a system in its entire life cycle: from an initial idea, to execution to liquidation. This requirement will be fulfilled when constant diagnosing is performed during system operation, enabling both the present technical condition evaluation and failure location. Routine maintenance and operating activities make up elements of the diagnosing process.

This study aims at an analysis of heavy fuel oil purification system of a marine power plant based on two diagnostic tests: one employing the Boolean matrix method and the other using the one-by-one testing. Besides, parameters of the heavy fuel oil purifier making up part of the system are examined.

Information on system state can be obtained by means of trials. Each of the trials can divide the set $E = \{e_z\}$, $z = \overline{1, n}$ of elements of an item into two subsets. The subset one that can be said not to include or to include damaged elements (respectively, positive or negative result of the trial), and subset two that cannot be thus described. The set $T_d \subset \Pi$ of trials, which makes it possible to differentiate all states W of an item being diagnosed, is called a diagnostic test. Generally, minimal tests or near-minimal tests should be used. The real number of trials feasible in a real item can be determined by means of item functional models. There are a number of methods for creating diagnostic tests using various branches of mathematics. Diagnostic tests are of various types, such as the method of one-by-one testing, Boolean matrix, information method, the method of group control, half-half split testing, optimization methods etc [3,4].

Diagnostic tests tend to utilize minimal or near-minimal tests. The real number of trials is determined using a functional model of an item, which in this case consists of graphs illustrating the flow of a fluid in a given installation. Examples of use of the Boolean matrix method and one-by-one testing refer to a heavy fuel oil purification system.

Figure 1 presents a flow graph illustrating a heavy fuel oil purification system. In order to illustrate and facilitate the use of diagnostic tests, the diagram also shows inlets of energetic fluids used in particular elements of the system.

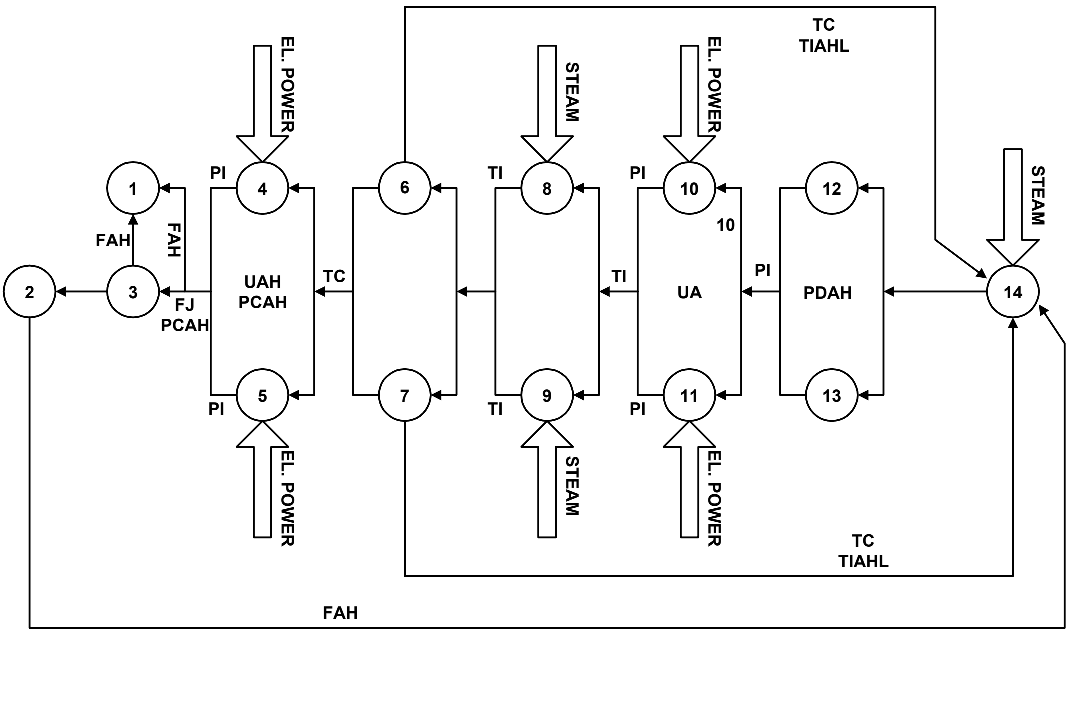

Fig. 1 Graph of a functional structure of fluid flow in a heavy fuel oil (*HFO*) purification system.14 – HFO settling tank; 13,12 – filters; 11,10 - pumps; 9,8 - heaters; 7,6 – three-way valves; 5,4 - purifiers; 3 - filtrator; 2 – HFO service tank; 1 – sludge tank

2. Application of the Boolean matrix method

For the graph presented in Figure 1, consisting of elements $E=\{e_1,e_2,e_3,...e_{14}\} = \{e_j\}$, $j = 1,2...14$ interacting between one another according to a functional diagram, the state is characterized by a set of 14 elements $W = \{w_0,w_1,...w_{14}\} = \{w_i\}$, $i = 0,1,...14$. W_0 denotes a full up state of the heavy fuel oil system, w_1 denotes fault of element e_1 etc. The set Π consists of 14 trials, with the trial π_j denoting control of an output parameter from j-th element. The adopted functional structure made up a basis for a table of states (table 1). Particular states, in which the system can be found are expressed by 14-digit binary numbers that illustrate the functioning of the system being diagnosed, where the place of zero corresponds to a faulty element. The columns of trial results π_j the value 0 for a given trial means that the value of the monitored parameter exceeded an admissible limit, while when 1 occurs, the value of a given parameter ranges within allowed limits. In order to simplify the further descript ion of the functional structure of fluid flow in the HFO purification system the author has introduced an additional notation of particular elements.

Table 1

States of the *HFO* purification system

SET OF STATES *W*		**SET OF TRIALS Π**													
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
0	11111111 111111														
1	01111111 111111														
2	10111111 111111														
3	11011111 111111														
4	11101111 111111														
5	11110111 111111														
6	11111011 111111														
7	11111101 111111														
8	11111110 111111														
9	11111111 011111														
10	11111111 101111														
11	11111111 110111														
12	11111111 111011														
13	11111111 111101														
14	11111111 111110														

The tables of states provide a source for building diagnostic tests for system state monitoring (*KSS*) and for the location of failures in the system (*LUS*). During the analysis, while building a matrix of a given test (e.g.: w_j, w_r), en element equal to 1 is created from the 1-0 system, whereas the systems 0-0 and 1-1 yield the value 0. To build a *KSS* test a subset of states *W* using pairs of trials (w_o, w_j), while to create a *LUS* test a subset of state pairs (w_j, w_r) is formed. Having adopted the structure shown in figure 1, a matrix for the *KSS* test was made (Table 2) and another matrix for the *LUS* test (Table 3). The value 1 in the columns of trial results denotes the discrimination of a state by means of the given trial π_j, and 0 denotes the non-discrimination of a state by the given trial (result of the trial π_j does not depend on the system state).

The results of an analysis of the matrix shown in Table 2 are used to define a diagnostic test for system state monitoring, having the form $T_d = \{\pi_1\}$, i.e. the test includes only the first trial.

Table 2

The state matrix for monitoring the state of the *HFO* purification system

SUBSET OF STATE PAIRS (w0, wr)	**SET OF TRIALS Π**													
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
(w0,w1)														
(w0,w2)														
(w0,w3)														
(w0,w4)														
(w0,w5)														
(w0,w6)														
(w0,w7)														
(w0,w8)														
(w0,w9)														
(w0,w10)														
(w0,w11)														
(w0,w12)														
(w0,w13)														
(w0,w14)														

3. Application of the one-by-one testing method

In the case when reliability data on an item diagnosed are not known, the method of one-by-one testing, also known as the infant method, is used. The method consists in subsequent verification of a hypothesis on possible failures of elements in a system. The number of trials is less by one than the number of all elements because if the diagnosis of the penultimate item proves it is operational, it follows that the last element is faulty.

Presented below is an example of a diagnostic model, based on the infant method. The elements are denoted as in Figure 1.

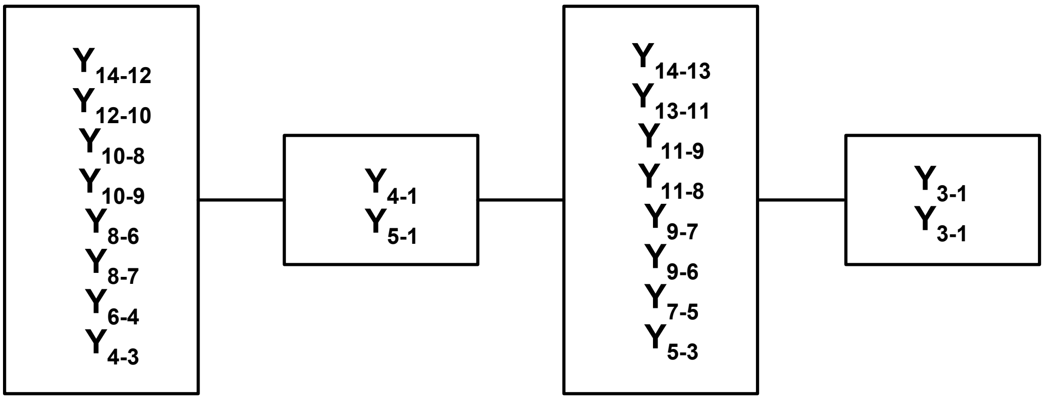

Fig. 2. A diagnostic model of a *HFO* purification system

Diagnosing with the use of above models is based on the verification of the diagnostic parameter Y_{n-m} (quantity measured between elements *n* and *m*). The particular components, branches or an entire system are said to be in the up state if, respectively, in a given set of elements the values of diagnostic parameters are found within a preset range. If a failure occurs in a system, one can identify the faulty element by one-by-one measurements. The measurement of parameters at the end of an installation informs whether the whole installation is in the up state, while a measurement at the end of a system branch informs that the elements of the branch are operational. If parameters in a branch are exceeded, the one-by-one testing between elements will indicate the faulty device.

4. Analysis of energetic fluids flow matrix in the HFO purification system

The functional structure (fluids flow graph) of the HFO purification system is presented in Figure 1. The diagram displays measurement points and alarm sensors, which are supposed to monitor a correct flow of a fluid. In order to examine whether the number of measurement points and alarm sensors fitted is sufficient for the complete control of heavy fuel oil purification the so called matrices of fluid flow were created.

The matrices contain the number of columns and rows that equals the number of elements forming the functional structure. They include data on the fluid flow between particular elements of the installation (0 - denotes no fluid flow, while 1 - denotes there is fluid flow). The places where measuring and alarm sensors are located are also marked in the matrix.

Table 3

Matrix of fluid flow in a *HFO* purification system

Comp.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	-	0	0	0	0	0	0	0	0	0	0	0	FA H
3	FA H	1	-	0	0	0	0	0	0	0	0	0	0	0
4	FA H PJ	0	FJ PJ P CAHL	-	0	0	0	0	0	0	0	0	0	0
5	FA H PJ	0	FJ PJ P CAHL	0	-	0	0	0	0	0	0	0	0	0
6	0	0	0	TC	0	-	0	0	0	0	0	0	0	TC TI AHL
7	0	0	0	0	TC	0	-	0	0	0	0	0	0	TC TI AHL
8	0	0	0	0	0	TJ	TJ	-	0	0	0	0	0	0
9	0	0	0	0	0	TJ	TJ	0	-	0	0	0	0	0
10	0	0	0	0	0	0	0	PJ TJ U A	PJ TJ U A	-	0	0	0	0
11	0	0	0	0	0	0	0	PJ TJ U A	PJ TJ U A	0	-	0	0	0
12	0	0	0	0	0	0	0	0	0	PJ P DAH	0	-	0	0
13	0	0	0	0	0	0	0	0	0	0	PJ P DAH	0	-	0
14	0	0	0	0	0	0	0	0	0	0	0	TJ TI AHL	TJ TI AHL	-

After an analysis of the fluid flow matrix (Table 3) and summing up control points for particular devices it has been found that all the system branches are permanently monitored. The system without places from which the operator could obtain information on the system state is subject to higher failure frequency.

5. Conclusions

The application of herein described methods for diagnosing a technical item requires first a preparation of a proper mathematical enabling a description of each possible technical condition of marine power plant device and installation.

By increasing the number of sensors we can more accurately determine the condition of technical items, which increases the costs of systems themselves and their operation. That is why unnecessary excess of measuring instruments should be avoided.

It should be borne in mind that even the best mathematical model will not fulfill satisfactorily its function without an appropriate number of parameters describing the item state. These parameters are understood as data from measurements of temperature, pressure, flow intensity, pressure differences, low and high fuel level in tanks, viscosity etc.

Such parameters supply information that enables accurate evaluation of the condition and proper functioning of individual installations. The *HFO* purification system analysis has shown that the use of a diagnostic test built with the boolean matrix method with 12 trials will provide for full control over the system.

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